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Effects of Coconut Sawdust on Mechanical Properties and Porosity of Concrete Mixtures

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The presence of coconut sawdust in North Sulawesi is very potential to be utilized as an alternative material for application in construction field. This paper aims to investigate experimentally the effect of coconut sawdust as an addition on concrete mixtures based on compressive strength, flexural strength and volume permeable voids tests. In this study, coconut sawdust with percentage of 2.5%, 5% and 7.5% by weight of cement was added into concrete mixture. The results show that concrete containing 5% of coconut sawdust exhibited highest compressive strength at 7 days with average value is 25.71 MPa while at 28 days the compressive strength is 30.50 MPa and there is no significant difference compared with 2.5% variation. When comparing the results of flexural strength test between 5% and normal cement concrete, the highest result is achieved by normal concrete reaching the value 6.78 MPa while for the concrete with 5% of coconut sawdust addition is only on 4.82 MPa. In terms of the volume of permeable voids, the results show that the porosity of concrete with coconut sawdust increased with the increase of percentage of coconut sawdust at 7 days but the values decreased as the age of curing increased.

1. Introduction

Growing concern on resource depletion has challenged many researcher and engineers around the world to work on renewable resources including the use of waste materials. Sawdust is a wood waste from timber industry which only been disposed or burned. There are lack of development on this material making it not fully utilized the true potential of this material although the availability is abundant. In concrete technology development, sawdust has become one of the natural fibers which can be used as an addition on concrete mixtures. In concrete, fibers can be used to control cracking development due to plastic and drying shrinkage [1]. Fibers can also help to carry the external load by improving the tensile and flexural strengths [2]. Reference [3] reported that fibers contain cellulose and hemicellulose with the tensile strength of cellulose can reach up to 2000 MPa. From some experimental works, it was found that there is an increment of compressive strength after the addition of sawdust on concrete mixtures. It was reported that the addition of sawdust as much as 5%, 10%, and 15% showed an impact on compressive strength and tensile strength [4]. The other study also found that there were no negative impact on chloride permeability and freezing-thawing due to the use of wood waste as cement replacement in concrete [5].

According to some previous researches, it is interesting to investigate the effect of coconut sawdust on concrete properties including compressive and flexural strengths since there are less reports available on the use of coconut sawdust as additive in concrete mixtures. The influence of using coconut sawdust on volume of permeable voids is also investigated in this study. Based on the objectives of this study, the results are expected to give value and more understanding on concrete production using coconut sawdust especially in North Sulawesi where the presence of coconut trees are available.

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2. Experimental methods

2.1 Materials

Materials for this research are Portland Composite Cement (PCC), fine aggregate sourced from Amurang Village (with size 4.75 mm) and coarse aggregate from Kema Village (with size 20 mm). The coconut sawdust was taken from local furniture home industry and passed sieve no. 16 (with size 1 mm). The coconut saw dust was dried in the oven under 110ºC for 5 hours before adding into the concrete mixtures. The chemical compositions of PCC and coconut sawdust are shown in Table 1 and Figure 1.

It can be seen that the coconut sawdust used in this experiment has high SiO_2 content of 52.52%. Three percentage of saw dust addition (2.5%, 5% and 7.5% by weight of cement) were used in concrete mixture for compressive, flexural and volume of permeable voids tests. The mixture proportions of concrete with and without coconut sawdust is tabulated in Table 2.

Table 1. Chemical compositions of PCC and Coconut sawdust

No.	Parameter	Compositions (%)	
		PCC	Coconut sawdust
1	SiO_2	20.92	52.52
2	Al_2O_3	5.49	
3	Fe_2O_3	3.78	14.99
4	CaO	65.21	13.98
5	Na_2O		
6	K_2O		16.88
7	MgO	0.97	
8	SO_3		0.23


Figure 2. Coconut saw dust image

Table 2. Mixture proportions of concrete containing coconut sawdust

Materials		Concrete sample types			
		0%	2.5%	5%	7.5%
Cement	kg/m^3	525	525	525	525
Fine Aggregate	kg/m^3	624	624	624	624
Coarse Aggregate	kg/m^3	978	978	978	978
Water	kg/m^3	186	186	186	186
Coconut saw dust	kg/m^3	0	13	26	39

2.2 Compressive Strength

Compressive strength test was conducted based on ASTM C-39 [6]. The cylinder mould with size 100 mm for its diameter and 200 mm for its height was used for testing at 7 and 28 days. For the treatment until 7 and 28 days the sample was kept on water in the water bath. When the age of the sample was fit for the test, put the sample out from the water bath, dry it then placed it on compressive machine for testing until reached the maximum load. The maximum load *(f'c)* was calculated using formula as in equation (1).

$$f'c = \frac{Maximum\ Load\ (P)}{Surface\ area\ of\ the\ tested\ sample\ (A)} \quad (1)$$

2.3 Flexural Strength

The flexural strength test was conduted based on ASTM C78 [7]. For flexural strength test, the sample was cast on beam mold with size of length = 50 cm, width = 10 cm, and height = 10 cm. After curing days, the sample was placed on the testing machine with third-point loading and the constant rate of load was applied up to the breaking point. The flexural strength of concrete was then calculated by using formula as in equation (2).

$$R = \frac{3PL}{2bd^2} \quad (2)$$

Where:

R	= Modulus of rupture (MPa)
P	= Maximum Load
L	= Span length (mm)
b	= average width of specimen, at the fracture (mm)
d	= average height of specimen, at the fracture (mm)

2.4 Volume of Permeable Voids

Volume of permeable voids (VPV) test was conducted based on ASTM C 642 [8] to estimate the percentage of voids in the concrete containing coconut sawdust at 7 and 28 days. The voids percentage is determined by boiling the 50 mm cut concrete specimens for at least 5 hours in a water tank at 105°C, weighing the samples in water, then measuring the percentage of boiled specimen with dried mass and mass in the water. The VPV of concrete specimens was calculated according to formula as seen in equation (3).

$$VPV = \frac{Mass\ after\ boiling - Mass\ oven\ dried}{Mass\ after\ boiling - Mass\ sample\ in\ water}\ x\ 100\% \quad (3)$$

3. Results and Discussions

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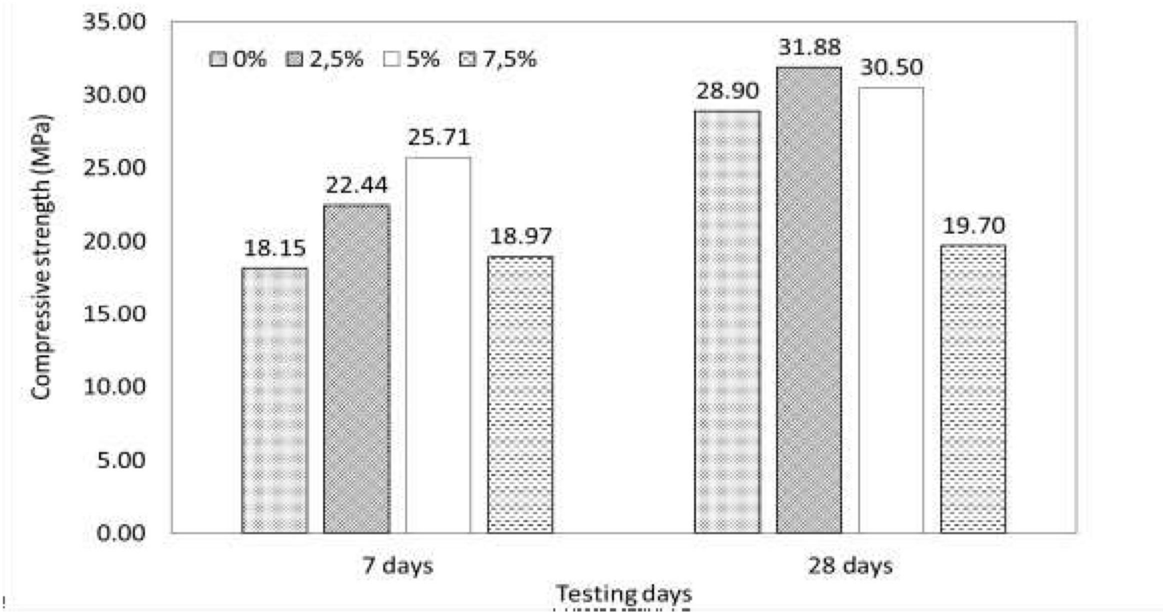

3.1 Compressive Strength

The results of compressive strength of concrete samples with and without coconut addition at 7 and 28 days are shown in Figure 3. It can be seen that there is an improvement of compressive strength after the addition of coconut sawdust in concrete mixtures with the maximum percentage of coconut sawdust is 5% by wt. The compressive strength value of concrete with 5% coconut sawdust reached up to 25.71 MPa at 7 days and 30.50 MPa at 28 days. These number are around 30% and 5% higher at 7 and 28 days, respectively, when compared to the compressive strength of normal concrete without coconut sawdust addition. Interestingly, concrete with 2.5% coconut sawdust addition also shows an improvement on compressive strength particularly at 28 days. However, increasing the addition of coconut sawdust up to 7.5% resulted in lower compressive strength. This is an indication that the dosage of coconut sawdust that can be used as an addition in concrete should not be more than 5% by wt. This result is also in relation to a study conducted by reference [9] where the compressive strength decreases as the increase of sawdust content. The density of concrete were also found decreased as the increased of sawdust content in concrete mixture.

Figure 3. Compressive strength of concrete with coconut sawdust at 7 and 28 days

3.2 Flexural Strength

On the flexural strength test, the results between normal concrete and concrete with 5% coconut addition after water curing at 28 days are compared as shown in Figure 4. Based on the results, it can be observed that coconut sawdust addition with 5% by wt. reduced the flexural strength of concrete from 6.78 MPa to 4.82 MPa, 28% lower than the flexural strength of concrete without coconut sawdust. This trend is also supported by the experimental results reported by reference [10] where the higher amount of sawdust, the lower the flexural strength. However, rapid increase at lates ages (56 days) was observed in concrete containing wooden sawdust. In this case, the ratio of cement and sawdust becomes the main parameter that should be considered for the strength development of concrete containing wooden sawdust.

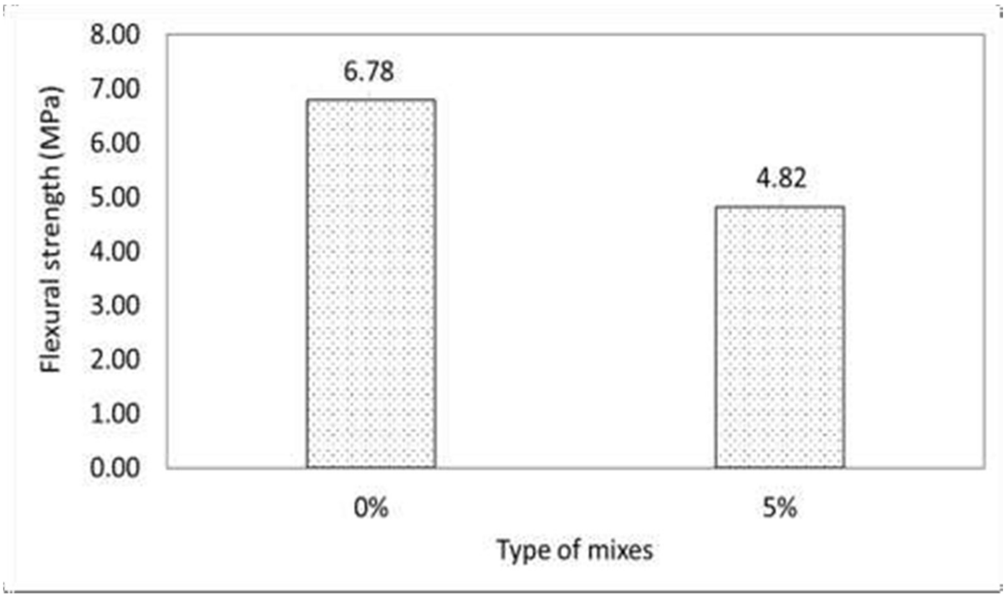

Figure 4. Flexural strength of normal concrete and 5% coconut sawdust addition at 28 days

3.3 Volume of Permeable Voids

Figure shows the percentage of volume of permeable voids of concretes containing coconut sawdust at 7 and 28 days. It can be clearly seen that the addition of coconut sawdust in concrete mixtures increases the volume of permeable voids. Among concrete samples containing coconut sawdust, the addition of 5% coconut showed lower percentage of voids compared to concretes with 2.5% and 7.5% coconut saw dust by wt. at 7 and 28 days. There is no significant difference was observed when comparing the voids percentage of normal concrete with 5% coconut sawdust concrete. On the other hand, concrete with 2.5% coconut sawdust addition also shows comparable results with 5% coconut sawdust concrete on the voids percentage at 28 days although at 7 days the volume of voids reached up to 17.82 %. This is an indication that in order to achieve better results on using coconut sawdust for concrete mixtures, method of mixing should be taken into account. Coconut sawdust has a tendency to absorb more water that reduces the workability of concrete, therefore, the use of chemical admixture with adjusted water/cement ratio to maintain the workability could be considered for future research. The effect of wood waste ash in increasing the water absorption of concrete is also commented by reference [5]. In this study, the water absorption of concrete was increased along with wood ash percentage that was also reduced the density of concrete.

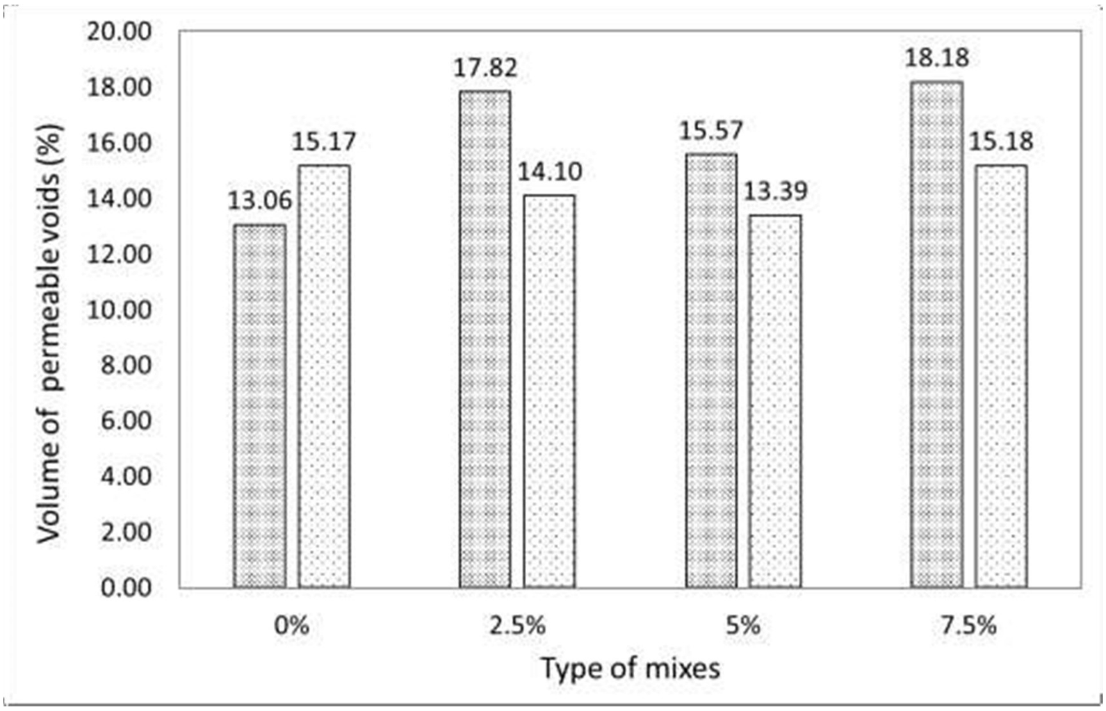

Figure 5. Volume of permeable voids of concretes containing coconut sawdust at 7 and 28 days

4. Conclusions

From the limited results in this experimental works, some conclusions could be drawn as follows:

1. The addition of coconut sawdust with percentage of 2.5% and 5% improves the compressive strength of concrete up to 31.88 MPa and 30.50 MPa, respectively. However, the strength decreases as the coconut sawdust content increases up to 7.5% by wt.
2. For the flexural strength, normal concrete achieves better strength with value of 6.78 MPa at 28 days, higher than the flexural strength of concrete with 5% coconut sawdust addition by wt. of cement. Further investigation on the use of coconut sawdust using percentage lower than 5% should be considered.
3. Volume of permeable voids of concrete with coconut sawdust at all variation of percentage are comparable with the voids volume of normal concrete especially at 28 days. Coconut sawdust has a tendency to absorb more water that reduces the workability of concrete, therefore, the use of chemical admixture with adjusted water/cement ratio to maintain the workability could be considered for future research.

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